



Spatio-Temporal Pattern of Potential Aerodrome Obstacles on Flight Safety Operations in Mallam Aminu Kano International Airport Kano-Nigeria

by

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Abstract

This study assessed the spatial pattern of the potential aerodrome obstacle on flight safety operations, in Mallam Aminu Kano International Airport. Quick Bird satellite images, coordinates from field survey using Different Global Positioning System (DGPS) and administrative map of the study area, were some of the data used for the study. Average nearest neighbor statistics was utilized to analyze the spatial patterns of distribution of the identified aerodrome obstacles. The obstacles were determined by establishing baseline of known length with the feature normal to the midpoint of the baseline. Two differential GPS points were formed at the end of the baseline. Two Theodolite readings were taken from each end of the baseline plus a distance. The result showed that the obstacles on the approach surface, runway, inner horizontal surface, conical surface and transition surface were clustered having a nearest neighbor index. While the obstacles on the take-off climb and the outer horizontal surface were dispersed with the index value greater than 1. Based on the findings, it was recommended that Nigeria being a member state of ICAO, should as a matter of urgency be ICAO e-TOD compliant (Electronic, Terrain and Obstacles data). This will go a long way in checking the menace of Aircraft/Obstacles collision to the barest minimum, so as to ensure regularity, efficiency and above all safety in aviation industry.

Keywords: Aerodrome, Flight Safety, Nearest Neighbour Index and Obstacles.

1. Introduction

The Aviation industry is a critical component of our national economy providing for the movement of people and goods throughout the world, which is also critical for economic growth. It is a fast-growing sector of the economy, providing a number of

social and economic benefits (Ahmed, 2011). Aerodrome is a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft. While, Aircraft could be defined as any machine that can derive support in the atmosphere from the reactions of air other than reactions of air against the earth's surface.

The safety of travelling by air is an absolute pre-requisite for air transport. Air transport is recognised as a very safe and fastest mode of transportation, but there are some challenges. Euro-control: Challenges of Growth study, 2008 stated that, no person shall, through any act or omission endangers the safety of an aircraft or person therein, or cause or permit an aircraft to endanger the safety of any person or property". As navigable airspace, where "heavier than aircraft can operate, it means that any obstacle, anywhere, need to be evaluated. The main reason of evaluating such obstacle according to ICAO is to control or prevent structures that could have a serious effect on aviation safety, especially in the vicinity of an aerodrome.

Sebastian *et. al*, (2008) observed that unmanned aerial vehicles (UAVs) performing reconnaissance survey for the police, news or the military must fly at low altitude. They pointed out that flying close to and among obstacles is difficult because of the challenges in sensing and observing small obstacles, also controlling a complex system to avoid obstacles in three (3) dimensions is usually difficult. Some aspects of collision avoidance are easier for air vehicles than ground vehicles. Any object close to the intended path of an air vehicle must be avoided as opposed to ground vehicles where deviations from the nominal ground plane indicate obstacles and are often not visible until they are close. The use of helicopters, rather than fixed wing aircraft also helps in case of any eventuality, because it is possible to come to a hover in front of an obstacle. The availability of appropriate sensors, logistical issues of mounting a vehicle with sufficient sensing, computing and communication gear which led to the closure of two out of the four runways at the Charles de Gaulle international Airport France. The two runways were shut down due to the fact that the police helicopters were operating at a very low level in an attempt to track the suspects of the Charlie Hebdo incidence in France (Jim, 2015).

According to (SA-CAR, 2015), any communications structure, buildings, whether temporary or permanent which has the potential to endanger the navigable airspace, or has the potential to interfere with the operation of navigation, surveillance systems, instrument landing systems and meteorological systems are referred to as Obstacles. Obstacles in the vicinity of an airport, whether they are natural or constructed, may seriously limit the scope of aviation operations into and out of the airport. It is essential that off-airport land use planning take full account of obstacles implications. An airport's obstacles limitation surface (OLS) is determined in accordance with ICAO (1987). Civil Aviation Act (2006) defined the airspace around the aerodromes to be maintained free from obstacles so as to permit the intended aeroplane operations at the aerodromes from becoming unusable by the growth of obstacles around the aerodromes. In Nigeria, Nigerian Civil Aviation Authority (NCAA) is empowered to prohibit and regulate installation of any structure which by virtue of its height or position is considered to be an

obstacle to safe operations. It is imminent to mention that Mallam Aminu Kano International Airport has been witnessing a lot of construction activities in and around the vicinity of the airport which may become obstacles to flight operation.

The most important role of aerodrome obstacles limitation surfaces (OLS) is to set and supervise the maximum height that an obstacle around an airport is allowed. This is usually referred to as Inner Horizontal Surfaces (IHS) or Conical Surface. The inner Horizontal Surfaces (IHS) is a circular surface, which has a height of 45m with a radius ranging from 2 to 4km, depending on the runway reference length. The conical surface slopes outward from the IHS with a slope angle of 5% up to a runway reference length. Where, one of these surfaces is protruding, an aeronautical study should be carried out to ensure that the obstacles do not affect the safety and regularity of operations to/from the airport (Teuge, 2009).

In most developing countries particularly Nigeria, several plane crashes have been recorded resulting from collision with obstacles within the vicinity of an aerodrome. For example, in June 1996, a plane crash occurred at Jos airport resulting from collision of an aircraft with a communication mast which led to loss of lives and property (Kurawa, 2009). Also, Sky Executive Aviation Services crash on the approach to Calabar Airport on 21st May, 2002 (Federal Ministry of Aviation, 2015). Another serious incident involving a Baggage tractor (DOUGLAS) Towing tug on the ramp collides with the aircraft while taxiing at Murtala Muhammed International Airport, Ikeja-Lagos, in January, 2008 (Accident Investigation Bureau, 2015).

Previous studies on aircraft/bird strike collision include: Dukiya and Gahlot (2012) carried out a research on the evaluation of the effect of bird strikes on flight safety operations at Mallam Aminu Kano International Airport, Kano. The study made use of aviation safety ranking value (ASRV) to evaluate and rank the risk of bird strikes species. Their result concluded that a significant number of varieties of bird species were observed in the vicinity of Kano airport and the propensity of these birds to collide with aircraft is real and this is a menace to the aviation industry. Ahmed (2011) conducted a study on the assessment of the effect of birds strike on flight safety operations in Mallam Aminu Kano international airport Kano, Nigeria. The result of the study came to conclusion that twelve of the bird species were involved in forty-four (44) strikes at the airport during the period 2001-2010. The study also revealed that most of the strikes occurred during the rainy seasons from May- October. Distribution of the bird strikes by phase indicates that 32% occurred on approach, 25% on landing roll, 20% on take-off, 4.5% on descend, 4.5% during climb, while 14% of these strikes the phase is unknown.

However, it is of interest to note that despite the potential risk pose by the Aerodrome obstacles none of the previous studies have focused on the spatial pattern distribution of potential aerodrome obstacles on flight safety operation in the study area. This became necessary because of the increase in the rate of urbanization that Kano is experiencing in recent years, which has led to construction of more buildings and other human activities taking place within the vicinity of the airport.

2. Objectives of the Study

The aim of the study was to analyse the spatial threat of potential aerodrome obstacles on flight operations in the study area. The aim will be achieved through the following specific objectives: -

- i. Identify and map out the potential aerodrome obstacles on flight safety operations in the study area.
- ii. Examine the distribution of spatial pattern of the potential aerodrome obstacles on flight operations in the study area.
- iii. Determine the level of conformity (locations) of the potential aerodrome obstacles as relates to ICAO Standards and Recommended Practices (SARPS)

3. The Study Area

The area investigated covers a radius of 10 nautical miles from the aerodrome reference point and is located between Latitudes $11^{\circ} 52' 30''$ N and $12^{\circ} 07' 30''$ N of the Equator and between Longitudes $8^{\circ} 27' 00''$ E and $8^{\circ} 42' 30''$ E of the Greenwich meridian (KNSG, 2004). It is bordered by Dawakin Tofa L.G.A., to the northwest, Minjibir and Gezawa L.G.A to the northeast, Warawa and Dawakin Kudu to the southeast and Madobi and Tofa L.G.A. to the southwest. The Metropolitan area of the state covers 499km². Kano state is characterized by low rainfall (850-870mm) and high rainfall of about 4200mm in a wet year, thus it has a distinct wet and dry season. The temperature is slightly above 30°C (Sarah and Charles, 1988) (Figure 1)

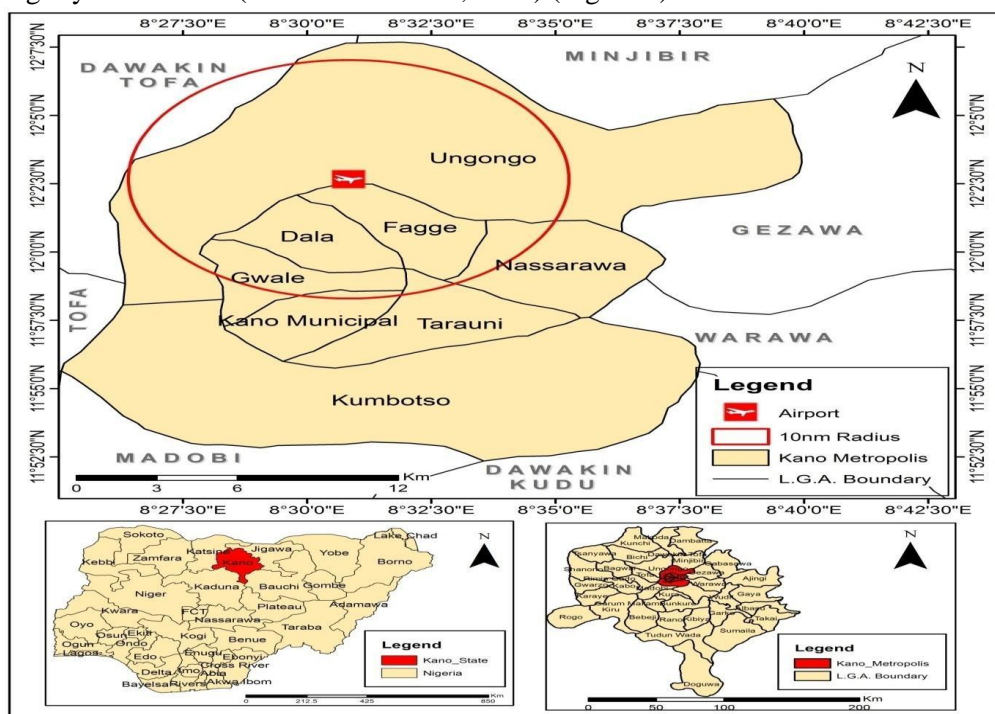


Figure 1: Kano Metropolis showing Location of Mallam Aminu Kano Int'l Airport

Source: Modified from the administrative map of Kano State (2019)

Kano State is located in the tropics, a region characterised by alternating wet and dry conditions, with annual rainfall of 850mm occurring between April/May and September/October with peak in July and August. The climate of Kano is also described as seasonally arid and in southern Kano rainy season average is about 150 days May to October. Mean annual rainfall in the southern parts is about 1000mm and in the north it is 635mm (Sarah and Charles, 1988).

The climate of Kano is described as Aw by Koppen, with both annual and seasonal variabilities wet years and dry years may record between 850 and 750mm (Ahmed, 2011). The temperatures are characterised by warm to hot seasons with the occurrence of the Harmattan between November and February. The climate of Kano state is characterised by four seasons which are dictated by the movement of ITD that control north easterlies and south west easterlies. The four seasons are: -Hot and dry season (*Rani*) it is between February, March and early May, warm and wet season (*Damina*) it is between May to September and it is characterised by surface runoff available for steam flow, warm and dry season (*Kaka*) it is normally around October to November it is referred to as harvesting season. And lastly there is cool and dry season (*Bazara*) it is around December to February and it is dominated by the action of north easterlies that brings hamattan.

4. Material and Methods

A baseline of known length was established with the feature normal to the midpoint of the baseline. Two nominal differential GPS points were formed at the ends of the baseline. Two theodolite readings were taken to the top of the feature from each end of the baseline plus a distance.

Differential Global Positioning System (DGPS) was used to get the coordinates xyz of the Aerodrome obstacles. Electronic Theodolites were used to get the direction of bearing of the identified obstacles (i.e. obstacles on the runway and take-off climb). Administrative map was used to identify the location of the study area and feature such as roads and L.G.A. boundary. Quick Bird imagery was used to extract the fixed physical features (both manmade and natural) within the vicinity of the Kano Aerodrome and its environs in ArcGIS 10.1 using the editor tool. This served as the base map for the study. While the obstacle limitation surfaces (OLS) are set of standards used to check the level of conformity in terms of obstacles penetration with ICAO Standards. Secondary data was also obtained from published and unpublished thesis; information from journals, text books, internets materials, research thesis was also used.

Reconnaissance Survey

Reconnaissance survey was carried out in order to get acquainted with the study area. During the reconnaissance survey observation on the ground scene of the study area was made.

Average Nearest Neighbour Analysis

The spatial pattern of distribution, of the potential aerodrome obstacles was achieved using average nearest neighbour within the approach, take off and taxing. This is to check if the distribution pattern is random, clustered or dispersed. The average neighbour in ArcGIS calculates the z-score and the nearest neighbour index. The pattern was determined based on these two parameters, the nearest neighbour index is given by:

$$\text{Nearest neighbour index} = \frac{\text{observed distance}}{\text{expected distance}}$$

The Average Nearest Neighbor tool measures the distance between each feature centroid and its nearest neighbor's centroid location. It then averages all these nearest neighbor distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analyzed is considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed. The average nearest neighbor ratio is calculated as the observed average distance divided by the expected average distance (with expected average distance being based on a hypothetical random distribution with the same number of features covering the same total area).

Identification And Mapping of Aerodrome Obstacles On Flight Safety Operations

In an attempt to identify and map aerodrome obstacles at Mallam Aminu Kano International Airport, Kano State, Nigeria, Differential Global Position System (DGPS) survey were carried at the Airport and its immediate environment (i.e. 10nm from the aerodrome reference point) using the World Geodetic System 1984 (WGS-84) reference system in accordance with existing ICAO Standards and Recommended Practices and accepted industry best practices. The mapping of the obstacles were carried out for different obstacle limitation surfaces (OLS). The objectives of the OLS is to define the airspace around the aerodrome to be maintained free of obstacles so as to permit the intended airplane operations at the aerodromes to be conducted safely and to prevent the aerodrome from becoming unusable by the growth of obstacles around the aerodrome. The distribution of obstacles for the different OLS is presented in the following sub-sections:

5. Results and Discussion

Trend of Aerodrome Obstacles in the Study Area

The spatial distribution of obstacles was identified and mapped for seven different obstacle limitation surface (OLS). The surfaces include: the approach surface, the take-off climb, the conical surface, runway, the inner horizontal surface, outer horizontal surfaces and transitional surface. Figure 2 represents the distribution of the aerodrome obstacles on the different surface while the types of obstacles where characterized in Table 1.

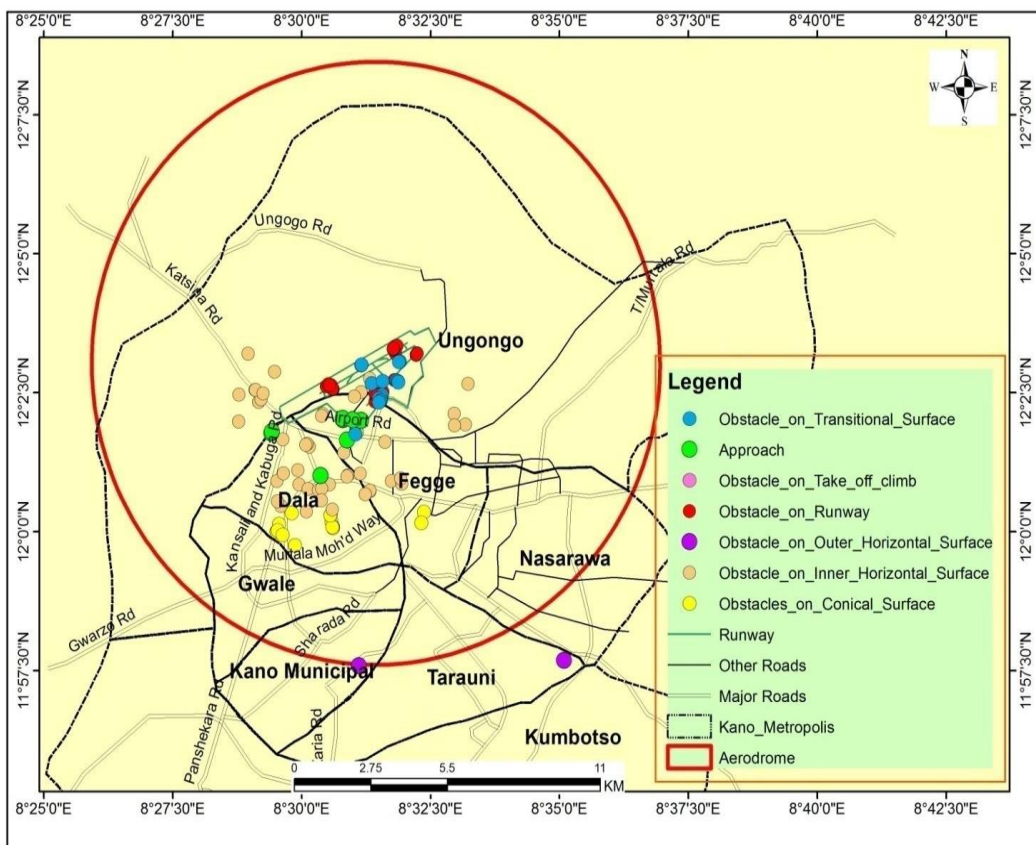


Figure 2: Distribution of Aerodrome Obstacles in the Study Area

Source: Field Survey and Author’s Analysis, 2019

Table 1: Types of Aerodrome Obstacles at MAKIA

Type of Obstacle	Frequency	%
Antenna	2	1.5
Building	4	3.0
Concrete Pillar	2	1.5
Instrument Landing System	36	26.6
Mast	81	52
Tree	20	14
Hill	1	0.7
Pole	1	0.7
Total	147	100

Author’s Analysis, 2019

It could be seen from Table 1 that 52% of the obstacles at the MAKIA aerodrome were communication masts which were placed for the resident within aerodrome for communication. 26.6% of the obstacles were the ILS (i.e. lighting that aids the landing of an airplane approaching the aerodrome’s runway). According to ICAO set recommended

practices and regulations stated that if an object or a proposed object which intrudes into navigable airspace requires, or will be required to be provided with, obstacle lighting. It could also be seen that 14% of the constitutes were trees. Only four were buildings which contributed about 3.0% of the obstruction. Antenna, concrete pillar, hill and pole contributed 1.5%, 1.5%, 0.7% and 0.7% respectively.

Obstacles on Approach Surface of the Aerodrome

The approach surface is an inclined plane or combination of planes which originate from the inner edge associated with each runway threshold, with two sides originating at the ends of the inner edge (ICAO, 2013). The spatial distribution and the type of obstacles on the approach surface of the aerodrome is presented in Figure 2:

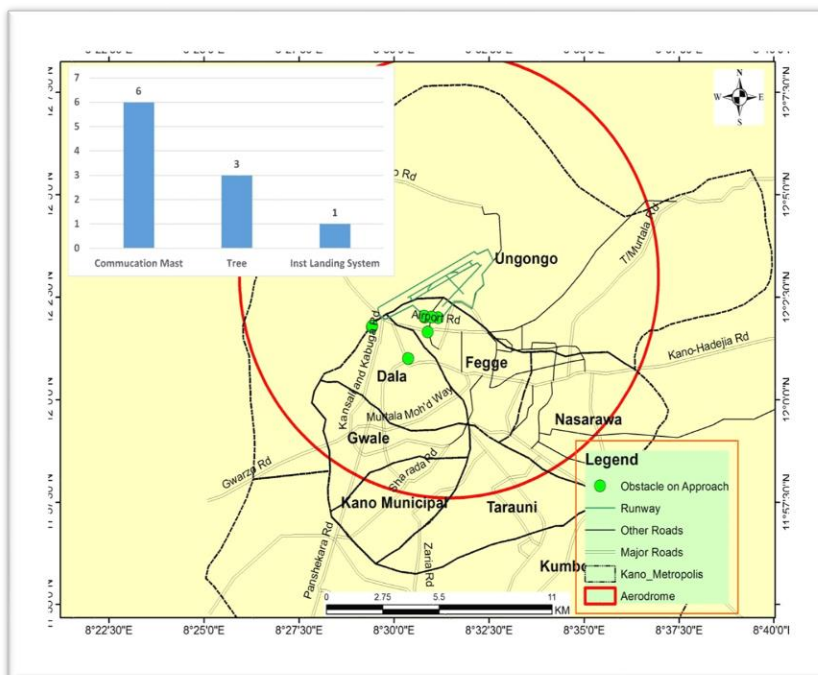


Figure 3: Obstacles on the Approach Surface of the Aerodrome

Source: Field Survey and Author’s Analysis, 2019

It could be seen from Figure 3 that 10 obstacles were observed on the approach surface of the aerodrome. Six of the obstacles were telecommunication mast, 3 were found to trees, and 1 was found to be light (Instrument Landing System ILS). According to ICAO any object be it man-made or natural on approach surface of an aerodrome may endanger the safety of an aircraft when preparing for landing.

Obstacles on Take-Off Climb Surface of the Aerodrome

The take-off climb surface of aerodrome is defined by an inclined plane (or other shape in the case of curved take-off) located beyond the end of the runway or clearway. Figure 4.3 represents the obstacles identified on the Take-off climb of the aerodrome.

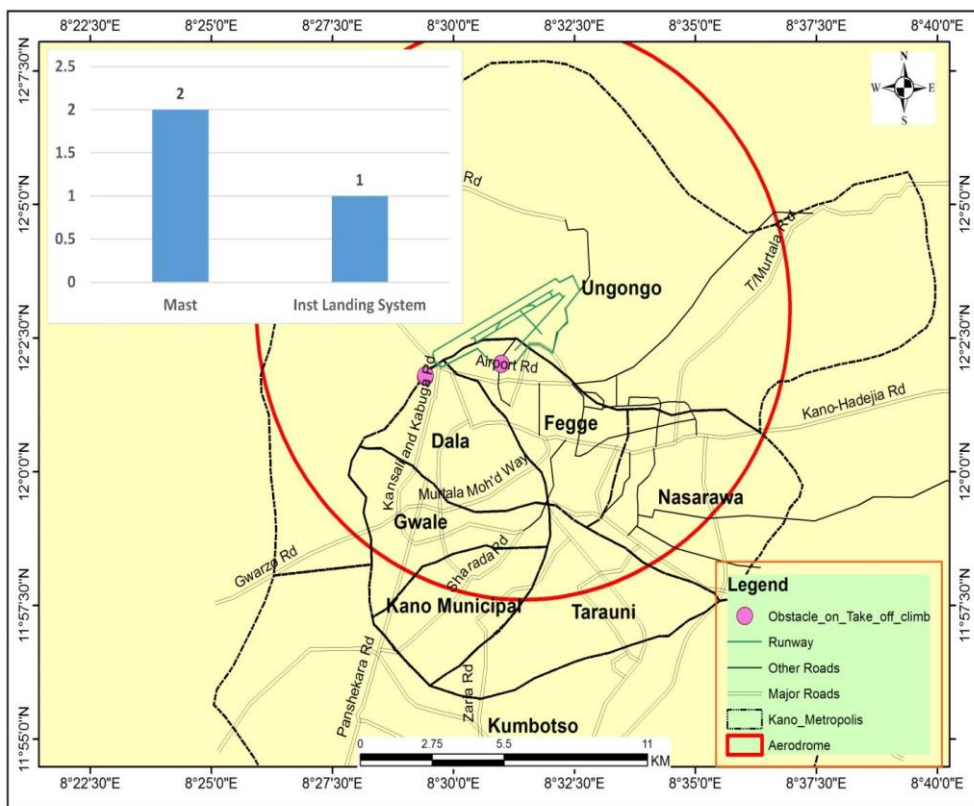


Figure 4: Obstacles on Take-Off Climb Surface of the Aerodrome

Source: Field Survey and Author’s Analysis, 2019

Figure 4 shows that three obstacles were found on the take-off climb of the aerodrome of which two of the obstacle were mast and 1 was found to be an instrument landing system (light).

Obstacles on Runway Surface of the Aerodrome

A runway is a defined rectangular area on a land aerodrome prepared for the landing and take-off of an aircraft. The obstacles on the runway of the aerodrome was identified and the result is presented in Figure 5

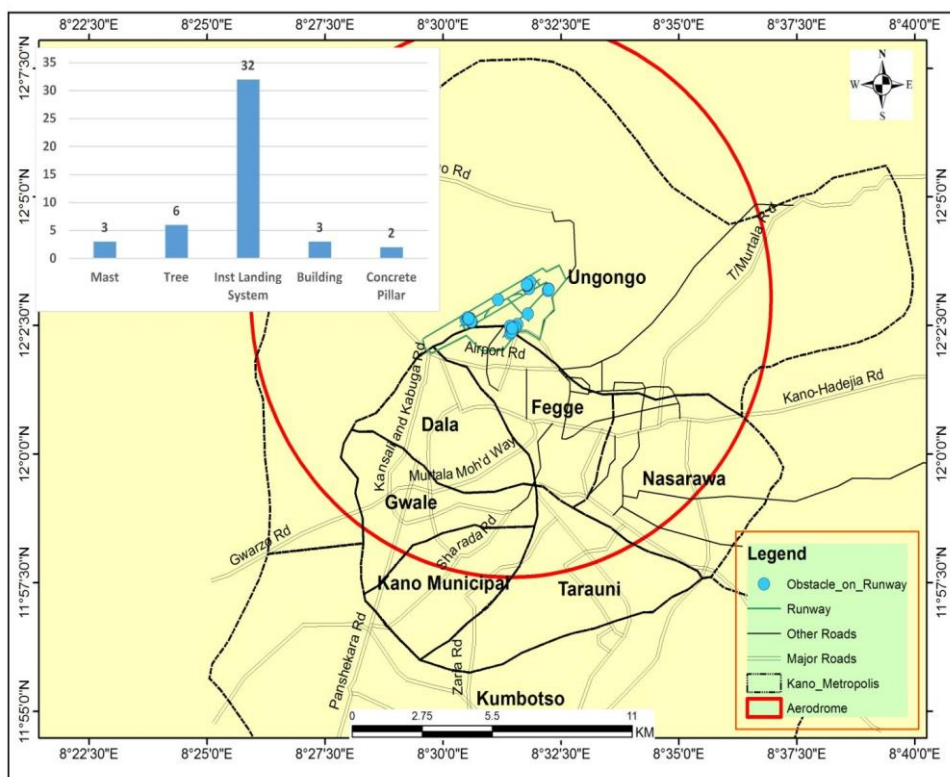


Figure 5: Obstacles on Runway Surface of the Aerodrome

Source: Field Survey and Author's Analysis, 2019

The data in Figure 5 showed 46 observed obstacles on the runway of Mallam Aminu Kano International Airport, Kano. 32 of the obstacles identified were Instrument Landing Systems (ILS), 6 six were trees, mast, buildings and concrete pillar were identified to be 3, 3 and 2 respectively. The high number of ILS (lighting) could be as a result of the instruction of civil aviation regulations which stated that an object or a proposed object which intrudes into navigable airspace requires, or will be required to be provided with, obstacle lighting (ICAO, 2013).

In order to analyse the pattern of the distribution of potential aerodrome obstacles in MAKIA and its immediate environment, the average nearest neighbour in spatial statistic toolbox of ArcGIS version 10.1 environment was utilized in analysing the pattern. The average nearest neighbour analyses calculates the nearest neighbour index (which is a measure of the distance between each obstacle centroid and its nearest neighbour's centroid location. It then averages all these nearest neighbour distances), the z-score and the p-value. These parameters were used as the basis for the determining whether the distribution is clustered, dispersed or random. The overall pattern of distribution is presented in Figure 2 and summary of the average neighbour analysis is shown in Table 1

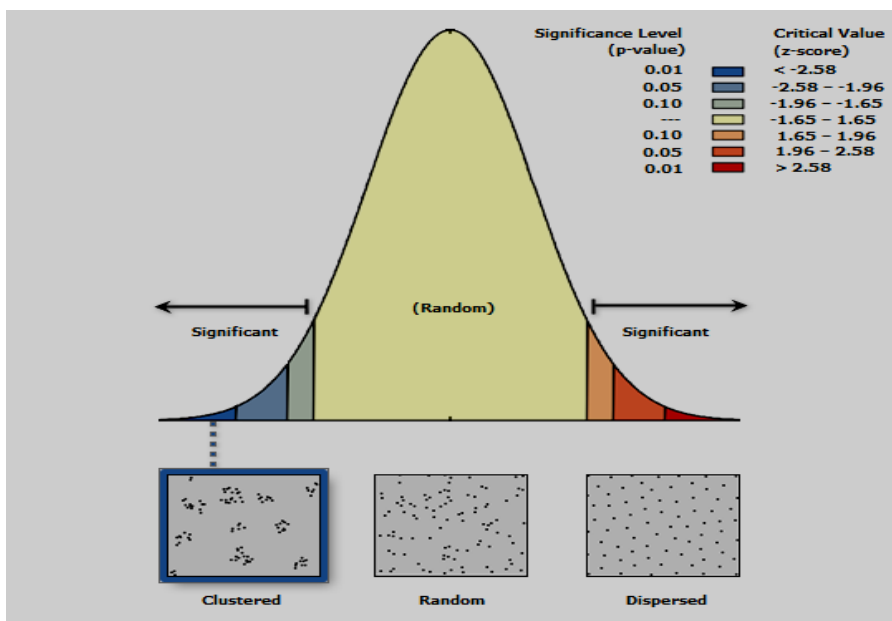


Figure 6: Overall Spatial Pattern of Distribution of Obstacles.

Source: Author's Analysis, 2019

Table 2: Overall Average nearest neighbor Statistic

Observed Mean Distance:	210.2 Meters
Expected Mean Distance:	427.6 Meters
Nearest Neighbor Ratio:	0.491672
z-score:	-11.790535
p-value:	0.000000

Source: Author's Analysis, 2019.

From table 2, it was observed that the observed average distance was 210.2m and the expected average distance was 427.6m. The nearest neighbour index was estimated from the two parameters and was calculated as 0.491672 and a z-score of -11.790535. According to Clark and Evans (1954), if the index (average nearest neighbor ratio) was less than 1, the pattern exhibited clustering. If the index is greater than 1, the pattern is toward dispersion. Based on this assertion, the result showed clustering in the overall spatial distribution of obstacles in the vicinity of.

Table 3: Summary of Average nearest Neighbour

Surface	Nearest Neighbor Ratio	Z-Score	P-Value	Description
Approach	0.413655	-3.54719	0.000389	Clustered
Take-off Climb	8.794884	25.82862	0	Dispersed
Runway	0.356475	-8.34978	0	Clustered
Inner Horizontal Surface	0.670626	-4.67306	0.000003	Clustered
Outer Horizontal Surface	171.9516	462.5077	0	Dispersed
Conical Surface	0.582206	-3.09556	0.001964	Clustered
Transitional Surface	0.736391	-2.01721	0.043674	Clustered
Total obstacle for all surfaces	0.490189	-11.8249	0	Clustered

Author's Analysis 2019

The equations used to calculate the average nearest neighbour distance index and z-score are based on the assumption that the obstacles being measured are free to locate anywhere within the study area (for example, there are no barriers, and all obstacles are located independently of one another). The nearest neighbour ratio, z-score and p-value for the various surfaces is summarized in Table 3.

The result from Table 3 indicates that the obstacles on approach surface, runway, inner horizontal surface, conical surface and transition surface were clustered. This is because the nearest neighbour ratio is less than 1, while those obstacles on the take-off climb and the outer horizontal surface were dispersed because they are greater than 1. From the study both clustered and dispersed pattern of distribution can be disastrous on the safety of an aircraft. However, the clustered obstacles may easily be avoided by both the pilot and the air traffic controllers while the obstacles that showed the disperse pattern has to be reduced to a minimal level or completely remove as the case may be, in order to avoid the risk of aircraft-obstacle collision in Mallam Aminu Kano International Airport.

6. Conclusion and Recommendations

From the findings of this study and with the rapid development of aviation technology, it has become increasingly necessary for aerodrome operators to review and ease the existing regulations for obstacle limitation surface. Therefore, the present study has used remote sensing, GIS, ground surveys and nearest neighbour analysis for visual inspections of all areas around the aerodrome in order to be sure that construction activity or natural growth likely to infringe any of the obstacle limitation surfaces is discovered before it becomes a problem. Therefore, the study shows that the obstacles on the approach surface, runway, inner horizontal surface, conical surface and transition surface were clustered while those obstacles on the take-off climb and the outer horizontal surface were dispersed.

Based on the findings of this research, the following recommendations are hereby made:

- The aerodrome operator should make use of the obstacle data collected and conduct periodic data analysis. This will allow the aerodrome operator to review the overall effectiveness of the obstacle control process. Through such analysis, the aerodrome operator will also be able to identify potential risks and hotspots, and develop mitigating measures to address them.
- The aerodrome operator should seek continuous improvement in the obstacle control process to ensure that safe aircraft operations can be carried out safely and efficiently at his aerodrome. The aerodrome operator should review the process and ensure that it is in compliance with the ICAO's requirements at all times.
- Each aerodrome operator should designate a member of its staff to be responsible for the continuing process of ensuring that aerodrome approach, departure and manoeuvring areas remain clear of obstacles which may jeopardize safety. The aerodrome operator must maintain constant vigilance to prevent erection of obstacles around the aerodrome. The aerodrome operator should establish a programme of regular and frequent visual inspections of all areas around the

aerodrome in order to be sure that construction activity or natural growth likely to infringe any of the obstacle limitation surfaces is discovered before it becomes a problem.

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